Assessing Changes in Brain Volume through MRI in the Progression of Dementia

1. Introduction

In the study of dementia, a condition at the heart of neurodegenerative research, MRI offers a crucial lens for observing the disease's progression. This study utilizes MRI data from the OASIS project to compare brain volume changes in patients with and without dementia.To capture the essence of these changes, two key neuroanatomical indicators are analyzed: normalized whole brain volume (nWBV) and Atlas Scaling Factor (ASF). These metrics serve as barometers for brain atrophy, reflecting the degenerative process inherent in dementia. The report utilizes mixed-effects Analysis of Variance (ANOVA) to probe both within and between-subject variations across multiple visits, thereby offering insights into the interaction of time and disease progression. Furthermore, a statistical power analysis ensures the robustness and reliability of the findings.

2. Data cleaning

a. Select the necessary columns

The raw dataset has a total of 16 columns and 294 rows, the columns I need are:

- Subject ID: Identification of the Patient
- Group: Demented, Nondemented and converted
- Visit: Visit Number
- nWBV: Normalize Whole Brain Volume
- ASF: Atlas Scaling Factor

b. Check whether there are missing values or outliers

There is no missing value because the count of nulls in all columns is zero.

3. Research questions

Research Question 1 (using mixed effects ANOVA):

How does the Atlas Scaling Factor (ASF) change over different visits and between groups (Demented, Nondemented, and Converted), and is there an interaction effect between visit number and group status on ASF changes?

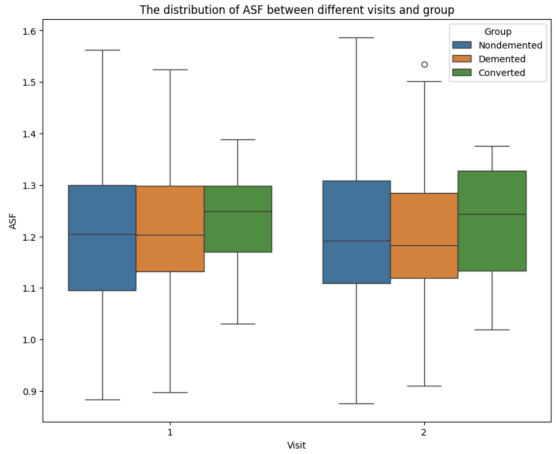
Research Question 2 (using mixed effects ANOVA):

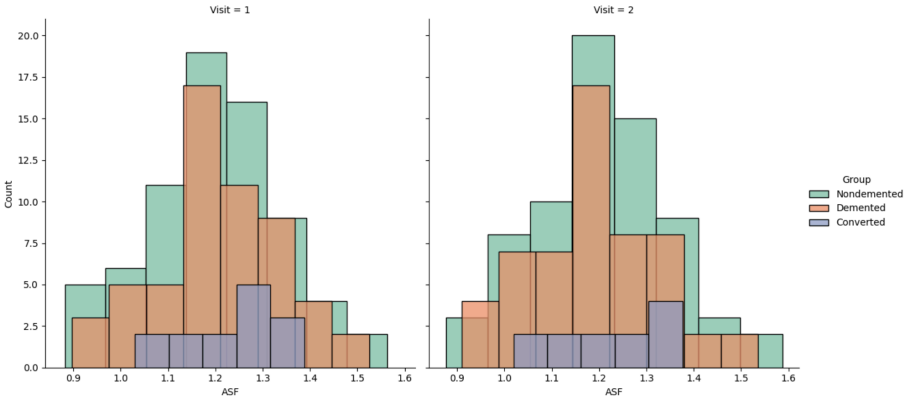
How does the Normalized Whole Brain Volume (nWBV) change over different visits between groups (Demented, Nondemented and converted), and is there an interaction effect between visit number and group status on nWBV changes?

3. EDA

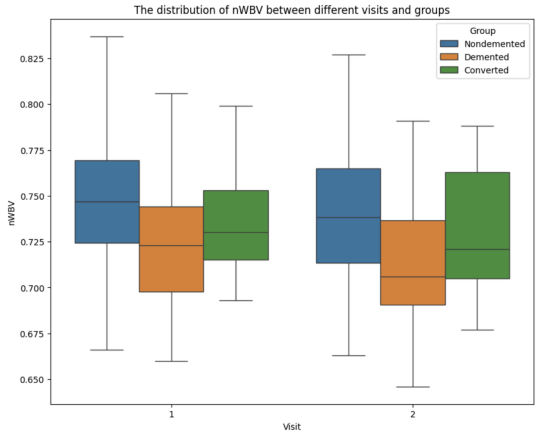
index	Visit	nWBV	ASF
count	294	294	294
mean	1.49	0.73	1.20
std	0.50	0.04	0.14
min	1	0.65	0.88
25%	1	0.70	1.12
50%	1	0.73	1.20
75%	2	0.76	1.30
max	2	0.84	1.59

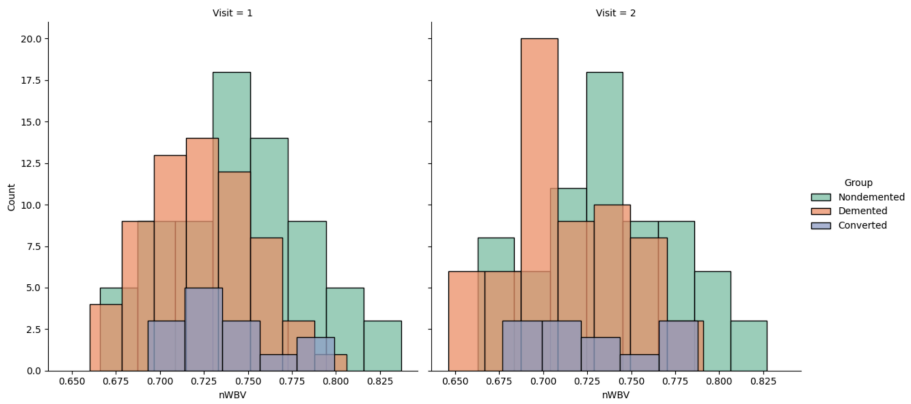
Interpretation:
Visits: An average of 1.49 suggests approximately an equal number of first and second visits.
nWBV: The average brain volume is 0.731, with a narrow spread of values.
ASF: An average of 1.203, suggesting varying degrees of brain atrophy across individuals.





The ASF distributions across the different visits and groups display a notable consistency, with the median ASF values holding steady between visits for the Demented, Nondemented, and Converted groups. Slight within-group variability is apparent, particularly for the Nondemented group in the second visit, as shown by the boxplot. Histograms for the first visit exhibit a bimodal distribution in the Nondemented and Converted groups, which becomes more unimodal in the second visit. This could indicate a convergence in ASF values or a reduction in variability over time. The Demented group maintains a stable unimodal distribution across both visits. Outliers observed in the boxplots suggest individual variations that may warrant closer examination.





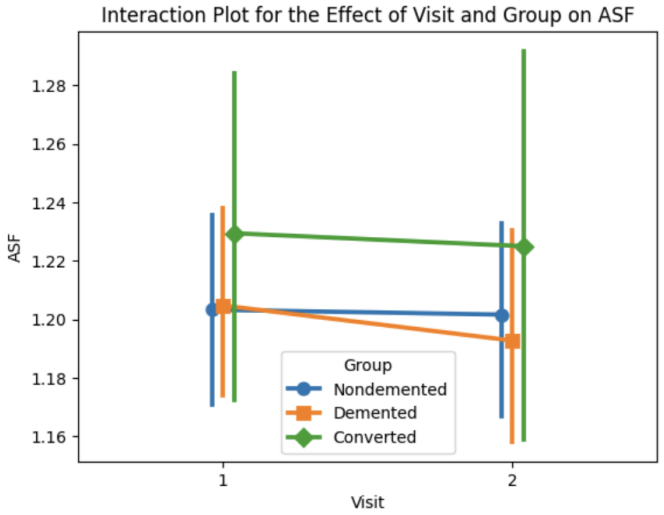
In the boxplot, all three groups display a range of nWBV values with the median notably consistent across visits, suggesting no substantial median change in brain volume over time within any group. The spread of nWBV, indicated by the interquartile ranges, is relatively stable across visits for all groups. Some outliers are visible, particularly in the Demented and Converted groups during the second visit, hinting at individual variations.

The histograms for both visits show overlapping distributions of nWBV for each group, with no dramatic shifts in the distribution peaks from the first to the second visit. Each group's distribution pattern is maintained across the two visits, reflecting a similar range of brain volumes over time.

4. Mixed Effects ANOVA Analysis

Research Question 1:

How does the Atlas Scaling Factor (ASF) change over different visits and between groups (Demented, Nondemented, and Converted), and is there an interaction effect between visit number and group status on ASF changes



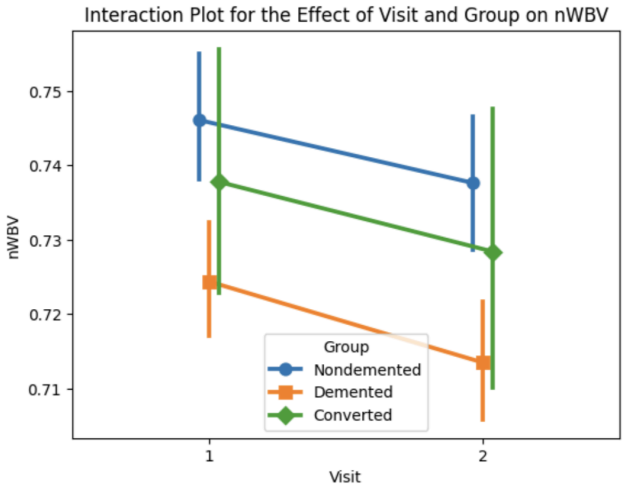
From the interaction plot, we can see the ASF values seem relatively stable for the Nondemented group from the first to the second visit, as indicated by the nearly flat line. In contrast, the Demented group shows a noticeable decrease in ASF values on the second visit, suggested by the downward trend. The Converted group exhibits an initial increase followed by a substantial decrease, as denoted by the peaked line.

index	Source	SS	DF1	DF2	MS	F	p-unc	np2	eps
0	Group	0.02	2	141	0.01	0.23	0.79	0.003	NaN
1	Visit	0.00	1	141	0.00	8.75	0.00	0.06	1
2	Interaction	0.00	2	141	0.00	1.03	0.36	0.01	NaN

The table above shows the results of a mixed-effect ANOVA, it indicates that there's no significant effect of the group on ASF ($p = 0.79 > 0.05$), and no significant interaction between group and visit on ASF ($p = 0.36$). However, there is a significant effect of the visit on ASF ($p = 0.003 < 0.05$), suggesting that ASF values change significantly between visits regardless of the group. The effect size for the visit ($np2 = 0.06$) suggests a small to medium effect.

Research Question 2:

How does the Normalized Whole Brain Volume (nWBV) change over different visits between groups (Demented, Nondemented and converted), and is there an interaction effect between visit number and group status on nWBV changes?



The interaction plot of nWBV shows there's a noticeable decrease in nWBV from the first to the second visit in the Demented and Converted groups, while the Nondemented group's nWBV remains relatively stable. The Converted group shows the greatest decline, suggesting a significant change in brain volume that may correspond to disease progression or transition.

index	Source	SS	DF1	DF2	MS	F	p-unc	np2	eps
0	Group	0.03	2	141	0.02	6.71	0.00	0.09	NaN
1	Visit	0.01	1	141	0.01	94.25	0.00	0.40	1
2	Interaction	0.00	2	141	0.00	1.53	0.22	0.02	NaN

The ANOVA table indicates that there's a significant effect of the group on normalized whole brain volume (nWBV) with a p-value of 0.0016, suggesting that nWBV differs between at least two of the groups (Nondemented, Demented, Converted). The effect size (np2 = 0.09) is relatively small, indicating a modest group effect on nWBV. There's a highly significant effect of the visit on nWBV ($p < 0.0001$), with a large effect size (np2 = 0.40), suggesting a substantial change in nWBV from the first to the second visit across all subjects. The interaction between the group and visit is not significant ($p = 0.22$), implying that the change in nWBV from the first to the second visit does not differ significantly between groups.

5. Assumption check for Mixed Effects ANOVA

Assumption 1: Mauchly's test of Sphericity: the result p-value is 1, which is greater than 0.05, and fails to reject the H0, so the assumption is met.

Assumption 2:

Visit	W	pval	normal
1	0.99	0.64	TRUE
2	0.99	0.699	TRUE

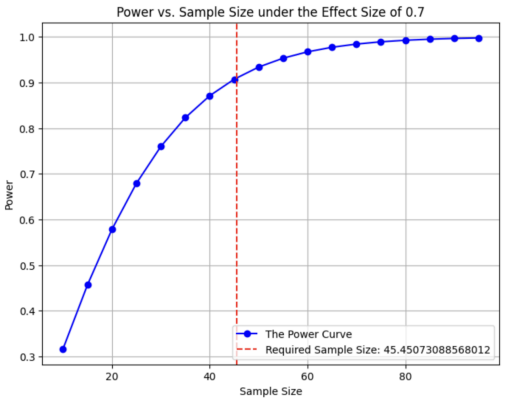
Normality is met because the p-value is > 0.05, then the true normal status.

Assumption 3:

index	W	pval	equal_var
Levene	0.1e	0.72	TRUE

Homogeneity of variance is also met, supported by the p-value is 0.72 > 0.05.

Power Plot for T-test:



With a power of 0.91, an effect size of 0.7, and an alpha level of 0.05, the calculated optimal sample size for each group is approximately 45.451, which we round up to an integer 46. This step for theoretical experimental design ensures that the study has enough sample size to detect the effects of interest. Greater statistical power means there is a higher possibility of correctly detecting a true effect.

6. Conclusion:

In conclusion, the Normalized Whole Brain Volume (nWBV) demonstrates significant variation between groups and over successive visits, though the combined influence of group and visit on nWBV does not reach statistical significance. Similarly, while the Atlas Scaling Factor (ASF) exhibits significant variation across visits, it does not vary significantly between different patient groups, nor is there a significant interaction effect between group and visit on ASF changes.